"The Molecular Volume of Solids." By EDWARD WILSON, M.A. Communicated by Professor STOKES, Sec. R.S. Received May 19. Read June 16, 1881.

The object of the present paper is to trace the relation between the molecular volume of any solid substance and its chemical constitution. This subject has engaged the attention of several previous inquirers, notably of Kopp, Schröder, and Hermann, but a review of their labours will be postponed till an exposition of the principles of this paper has been given. Such an arrangement, it is thought, will very much facilitate a comparison between the views and results of the present writer, and those of his predecessors in the same field of inquiry.

The molecular volume of any solid substance may be defined to be the weight of the molecule divided by the specific gravity of the substance. The weight is known in terms of the standard unit, if the chemical composition be known. The specific gravity may be determined by experiment. Then we may form either of the equations—

$$\text{Volume of molecule} = \frac{\text{weight of molecule}}{\text{specific gravity}}.$$

$$\text{Specific gravity} = \frac{\text{weight of molecule}}{\text{volume of molecule}}.$$

Another definition might be given as follows:—Every solid and liquid substance may be conceived as made up of molecules separated from one another by intervals of space, and kept apart by the repulsive forces which each molecule exerts on the molecules adjacent to it. At a certain distance the molecules cease to repel, and beyond that distance they attract one another; consequently, any molecule may be regarded as situate at the centre of a sphere within which any similar molecule would be repelled. This sphere may be called the sphere of repulsion, and the volume of the molecule may be defined as the volume of its sphere of repulsion. This definition is more suitable to the gaseous forms of matter, where the molecular volume is determined by observations on the interdiffusion of gases according to the plan adopted by Professor Loschmidt of Vienna. It is easy to show that according to this definition the molecular volume of any solid substance is equal to its molecular weight divided by its specific gravity.*

Each atom which enters into the composition of a molecule has a known and invariable atomic weight, and the weight of the molecule is the sum of the weights of the component atoms. In like manner

* *Vide* note.

the simple *monatomic* molecule of any element must have a determinate and invariable volume if the element could be reduced to the monatomic condition, and this volume may be defined as its atomic volume. But an element does not carry its atomic volume unchanged into its compounds in the same way that it carries its atomic weight; indeed, it is not probable that an atom of a compound molecule has any volume at all (except, of course, in so far as the mere matter of the atom may have a volume) in the sense of occupying exclusively of other atoms a discrete portion of space. The whole volume of the molecule is shared by its constituent atoms in common, and no separate portion of its space can be assigned exclusively to any one particular atom; nevertheless, each atom of the molecule must play its part in the formation of the common volume, and therefore a certain proportion of that volume may be attributed to each atom in it.

The invariable and all-important atomic volumes defined in the preceding paragraph cannot be the subject of direct experimental investigation, except perhaps in the case of the few elements, such as mercury, cadmium, and zinc, which are known to be monatomic in the gaseous state at terrestrial temperatures, though all the elements may be conceived as capable of thus existing under suitable conditions. The atomic volumes must in the case of each element be deduced from a comparison of the specific gravities of the various compounds in which that element figures as a constituent. The first point to be aimed at is to discover, by means of comparisons, the values of these atomic volumes, because they of necessity form the only sound and rational basis of all speculations on the volumes of compound molecules. There exists no other firm ground or secure starting point; atomic volumes are to molecular volumes what atomic weights are to molecular weights.

When two or more atoms combine to form a chemical compound, a very intimate union of some sort takes place between the atoms, of the real nature of which we are, in the present state of science, profoundly ignorant; but at any rate, a new molecule is formed with a new volume, and the question arises as to what relations subsist between this new volume and the atomic volumes of the components of the molecule. This is the problem which it is sought to solve, and the answer, perhaps, may best be given by the enunciation of the two following propositions :—

(1.) When any number of *similar* atoms combine, the volume of the resulting molecule is equal to that of the uncombined atom.

(2.) When *dissimilar* atoms combine, the volume to be attributed to each atom is some submultiple or simple aliquot part of its atomic volume, and the resulting molecular volume is the sum of these.

The somewhat speculative character of the above views will not escape the notice of any one, but before entering upon an explanation

of the tables which follow, the author thought it right to state the physical conceptions by which he was guided in his work. It must, however, be premised, as will appear more fully in the sequel, that these conceptions are provisional only, and should they hereafter prove erroneous, their invalidity would not affect the truth of the main result arrived at, which it is now proper to formulate in the shape of a general proposition as follows:—

(3.) Every element is capable of assuming different volumes in its various compounds, but these diverse volumes always bear to each other a simple numerical proportion, such as 1 : 2, 1 : 3, 2 : 3, &c., &c.

Attention must now be directed to the tables which follow, and which contain the evidence for the principles put forward in this paper.

Table I contains a list of the molecular or atomic volumes. The expression "molecular *or* atomic" is used as implying that the two values are identical, as indeed they must be by virtue of the principle enunciated in proposition (1). It will be observed that by virtue of the same principle equal molecular volumes are attributed to each of the allotropic forms of an element, the allotropism being supposed to consist in the different number of atoms contained in their respective molecules. With regard to the third column of the same table, it should be pointed out that, since chemists are possessed of no means of determining the number of atoms in the molecule of an element in the solid state, the molecular weights here assigned to the elements have been chiefly derived from a consideration of the volumes which the element is found to assume in the various substances of which it is a constituent. The atomic volumes of the elements whose specific gravities in the solid form are known, have been deduced from the specific gravities of such elements and their compounds conjointly, but the atomic volumes of such elements as hydrogen, oxygen, and nitrogen, whose specific gravities in the solid form are unknown, have been deduced from the specific gravities of their compounds alone, without the assistance to be derived from the specific gravity of the element itself. These last-mentioned compounds, however, are so numerous that their atomic volumes may be considered to be determined with greater accuracy than those of any of the other elements, with the exception of carbon.

It would be impossible to present the evidence in favour of the preceding propositions without an adequate notation, and, therefore, it is necessary to explain the system of notation that has been adopted. The atomic volume of each element is represented in the tables by the ordinary symbol used to denote that element, accented; whilst the submultiple of its atomic volume which the element assumes in a particular molecule is indicated by a suffix. Thus the atomic volume of potassium (90) is represented by K'; whilst K'_3 in an expression for the molecular volume of any substance containing potassium

would mean that the volume to be ascribed to potassium in that particular molecule is found by dividing the number 90 by 3, and then multiplying the quotient by the number of atoms of potassium in the molecule. Let us take an illustration from Table (IX). The molecular weight of potassium sulphate is expressed by K_2SO_4; the expression for its molecular volume is $K'_6S'_6O'_4$, which means that the number K′ (=90) has to be divided by 6 and the quotient multiplied by 2; the number S′ (=96) has to be divided by 6; the number O′(=20) has to be divided by 4, and the quotient multiplied by 4, and that the sum of the resulting numbers (30+16+20=66) is the molecular volume of potassium sulphate. The specific gravity is then obtained by dividing the molecular weight by the molecular volume: thus the specific gravity of potassium sulphate $=\frac{174}{66}=2{\cdot}636$, which agrees very well with its observed value $=2{\cdot}640$.

Another method of notation might have been adopted which has the advantage of getting rid of the accent and exhibiting both the molecular weight and volume in one and the same formula. Thus both the molecular weight and volume of potassium sulphate might be expressed by $K_{\frac{2}{6}}S_{\frac{1}{6}}O_{\frac{4}{4}}$, if the numerators of the fractions are understood to represent the number of atoms and the denominators the submultiples of the atomic volumes.

It is now necessary to explain more in detail, how the fundamental numbers of column IV, Table I, have been obtained. In the first place it may be observed that these numbers are always some multiple of the *atomic* weight of the element divided by its specific gravity; but that it requires an examination of the compounds of the element to determine what this multiple ought to be. Let us take one or two illustrations. The atomic weight of sodium divided by its specific gravity is 24, and an examination of the compounds of sodium discloses the fact that this element assumes in its compounds most frequently the volumes 8 and 12, and occasionally 24: the number 2, therefore, is the proper multiple in this case, and the fundamental number to be assigned to sodium is 48. Again, the atomic weight of iodine divided by its specific gravity is 25·6, but the most frequent volume of iodine in its compounds is 32 and, less frequently $21\frac{1}{3}$: the number 5 therefore is its proper multiple, and the fundamental number to be assigned to iodine is 128. For $25{\cdot}6\times5=128$, whilst 32 and $21\frac{1}{3}$ are respectively one-fourth and one-sixth of the same number. One more instance, perhaps, will suffice. The atomic weight of boron divided by its specific gravity is about =4, whilst its compound volumes are 7 and 14: whence 7 is the proper multiple and 28 its fundamental number.

Ammonium (NH_4) and cyanogen (CN) may be treated as simple elements, having as fundamental numbers the sum of the fundamental numbers of their constituents, viz., $N'+4H'=24+32=56$ and

$C'+\dot{N}'=32+24=56$ respectively. The meaning of this is that the components of these radicles always undergo a like condensation. Water of crystallisation has a volume $H'_4O'_2=14$, whilst that of ammonia in ammonia-compounds is $N'_2H'_4=18$.

The tables which accompany this paper will be found to contain pretty strong evidence of the truth of a conjecture first made by Kopp with regard to oxygen, viz., that an element in one and the same compound may undergo different condensations if it enters into the composition of two *distinct* radicles. Hydrated ammonium sulphate, $(NH_4)_2SO_4.H_2O$, affords a good illustration of this, for its molecular volume is $(NH_4)'_3S'_6O'_4H'_4O'_2$, and it will be observed that the hydrogen in the ammonium radicle is condensed to one-third, whilst in the water of crystallisation it is condensed to one-fourth, and again the oxygen in the acid radicle is condensed to one-fourth, whilst in the water it is only one-half.

The following circumstance is well worth consideration. Many substances, having the same chemical composition, appear to possess two distinct specific gravities, and therefore different molecular volumes; a good instance of this is to be found in mercuric sulphide, (HgS), which, as cinnabar, has a specific gravity of about 9·0, but in its amorphous state, a specific gravity of about 7·6, corresponding to molecular volumes $Hg'_6S'_6$ and $Hg'_4S'_6$ respectively: (HgS) has also sometimes a specific gravity intermediate between these limits, indicating an admixture of the two states. These mixtures are rather puzzling to any theory of molecular volumes, just as the densities of gases at temperatures when they are undergoing dissociation appear to be anomalous according to Avogadro's law. Perhaps these substances might not inappropriately be called bivolumetric or disteric bodies; a few examples of such compounds are given in the following table:—

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Silicic dioxide (crystalline)...........	SiO_2	$Si'_4O'_8$	2·688	2·690
Silicic dioxide (amorphous)...........	”	$Si'_4O'_4$	2·200	2·200
Zirconium dioxide....	ZrO_2	$Zr'_4O'_8$	5·655	5·624
” ”	”	$Zr'_4O'_4$	4·588	4·35—4·90
Titanium dioxide (rutile).............	TiO_2	$T'_2O'_8$	4·256	4·250
Titanium dioxide (anatase)	”	$Ti'_4O'_6$	3·875	3·890
Cobalt sesquioxide....	Co_2O_3	$Co'_4O'_4$	5·627	5·600
” ”	”	$Co'_4O'_3$	4·811	4·814

There is one more circumstance deserving mention, and that is, the

invariability of the volume of the constituents of the acid radicle in salts of the acid; for instance, in upwards of 60 sulphates, the radicle SO_4 has the same volume $S'_6O'_4=36$. It is true, the carbonates appear to form an exception to this rule, the radicle CO_3 having in some cases the volume $C'_4O'_4=23$, and sometimes the volume $C'_8O'_4=19$, and curiously enough, the oxalates follow suit in indicating two volumes for the radicle C_2O_4, viz., $C'_4O'_4=36$, and $C'_8O'_4=28$.

The observed specific gravities, with a few exceptions, have been taken from Clarke's "Constants of Nature," being No. 255 of the Smithsonian Miscellaneous Collections, a very compact and useful volume, which contains almost all the determinations that have been made by observers in all parts of the world.

We may now proceed to point out the very fair agreement between results obtained on the present theory and those reached by Professor Loschmidt by quite a different method, namely, by observations on the interdiffusion of gases. A simple inspection of the following table will show that the molecular volumes obtained on the principles of this theory agree very well with those arrived at by Loschmidt.

Comparison of the results of the present theory with those obtained by Professor Loschmidt from his experiments on the inter-diffusion of gases.

Substance.	Molecular volume.	Present theory.	Loschmidt.	
			I.	II.
H_2	H'_2	8	7	7
CO	$C'_2O'_2$	26	25	25
N_2	N'_2	24	26	24
NO	$N'_2O'_2$	22	24	23
O_2	O'_2	20	22	21
HCl	$H'_2Cl'_2$	26·5	26·3	26·3
Cl_2	Cl'_2	45	45·6	45·6
H_2O	$H'_2O'_2$	18	18	18
H_2S'	$H'_2S'_4$	32	33	33
CO_2	$C'_2O'_2$	36	36	35
N_2O	$N'_2O'_2$	34	37	35
SO_2	$S'_4O'_2$	44	48	48
NH_3	$N'_2H'_2$	24	23·5	22·5
CH_4	$C'_2H'_2$	32	35	28
C_2N_2	$C'_2N'_2$	56	54	56

Kopp's labours on molecular volumes were devoted chiefly to liquid substances, which are beyond the scope of this inquiry. The following brief account of his views on the molecular volumes of solids is derived from Miller's "Chemistry." Kopp supposes that, in the case

of the oxides, oxygen has three distinct volumes, 16, 32, and 64 (his numbers are adapted to the atomic weight of oxygen=100), which are in the simple numerical proportion 1, 2, and 4, but he never extends this principle to the other elements, unless it be, perhaps, to chlorine and the lighter metals; for, in the chlorides, the two values which he assigns to chlorine, 196 and 245, are in the ratio of 4 : 5; but then it is necessary to assume new volumes for the metals, which, like potassium, sodium, calcium, and magnesium, undergo condensation in the act of combining; and the volumes thus assumed for them exhibit no simple relation to the metals in an uncombined state. To the acid radicle SO_4 in the sulphates two volumes are likewise assigned, 186 and 236, which bear no simple relation to each other, and are not derived from the constituents of the radicle. To the radicles CrO_4, CO_3, and NO_3, in the chromates, carbonates, and nitrates, are assigned the volumes 228, 151, and 179, but then it does not appear that any connexion is traced between these numbers and the components of the respective radicles.

Schröder propounds the following principle:—"In every solid compound the volume measure (volume-maas) or the stere, of one of its elements, which, through the forces acting during crystallisation, determines all the other components and respective constituents, causes equal volume measures to take up equal steres. In other words, one of the elements assimilates all the others."

The number of atoms of each element in a compound is indicated in the ordinary manner by a whole number placed to the right of the under side of the symbol, and the number of its steres by a whole number to the right of the upper side. The stere is distinguished by an overstroke, and the observed and calculated volumes by a similar understroke. The element in a compound which determines the stere is also indicated by an overstroke; thus metallic silver is $\overline{Ag_1^2}=2\times\overline{5{\cdot}14}=\underline{10{\cdot}28}$, observed volume$=\underline{10{\cdot}28}$. Again, the chloride, bromide, and iodide of silver are represented thus:—

$$\overline{Ag_1^2}Cl_1^3=5\times\overline{5{\cdot}14}=\underline{25{\cdot}70}\text{ obs. vol. }=\underline{25{\cdot}70}.$$
$$\overline{Ag_1^2}Br_1^4=6\times\overline{5{\cdot}14}=\underline{30{\cdot}81}\quad\text{,,}\quad=\underline{30{\cdot}81}.$$
$$\overline{Ag_1^2}I_1^6=8\times\overline{5{\cdot}14}=\underline{41{\cdot}12}\quad\text{,,}\quad=\underline{41{\cdot}12}.$$

From this it is seen that in all these compounds the silver stere dominates.

Mercury has a stere=5·52. Thus:—

Mercurous oxide$=\overline{Hg_2^5}O_1^2=7\times\overline{5{\cdot}52}=\underline{38{\cdot}64}$ obs. vol. $\underline{38{\cdot}64}$.

Mercuric oxide$=\overline{Hg_2^5}O_2^2=7\times\overline{5{\cdot}52}=\underline{38{\cdot}64}=2\times\underline{19{\cdot}38}$ obs. vol. $\underline{19{\cdot}32}$.

Amorphous black cinnabar $=\overline{Hg^5_2}S^6_2=11\times\overline{5\cdot52}=60\cdot72=2\times\underline{30\cdot36}$ obs. vol. $\underline{30\cdot36}$.

Red rhombohedric cinnabar $=Hg^5_2\overline{S^6_2}=11\times\overline{5\cdot30}=58\cdot30=2\times\underline{29\cdot10}$ obs. vol. $\underline{29\cdot10}$.

The black cinnabar is distinguished from the red by the fact that, in the former, the mercury stere dominates, whilst in the latter it is the sulphur $=\overline{5\cdot30}$.

The mercury in its chlorides and bromides, and also in the cyanide is present as Hg^3_1, and not as Hg^5_2, thus :—

Mercurous chloride $=\overline{Hg^3_1}Cl^2_1=6\times\overline{5\cdot52}=\underline{33\cdot12}$ obs. vol. $=\underline{33\cdot12}$.

" bromide $=\overline{Hg^3_1}Br^4_1=7\times\overline{5\cdot52}=\underline{38\cdot64}$ " " $=\underline{38\cdot64}$.

Mercuric chloride $=\overline{Hg^3_1}Cl^6_2=9\times\overline{5\cdot52}=\underline{49\cdot68}$ " " $=\underline{49\cdot68}$.

" bromide $=\overline{Hg^3_1}Br^8_2=11\times\overline{5\cdot52}=\underline{60\cdot72}$ " " $=\underline{60\cdot72}$.

" cyanide $=\overline{Hg^3_1}Cy^9_2=12\times\overline{5\cdot52}=\underline{66\cdot24}$ " " $=\underline{66\cdot24}$.

Manganese oxides and silicates.—Metalic manganese has, according to John, the volume $6\cdot9=\frac{1}{2}$ magnesium.

$$Mn^5_4=5\times\overline{5\cdot52}=27\cdot6=4\times\underline{6\cdot9}\text{ obs. vol.}=\underline{6\cdot9}.$$

Pyrolusite $=Mn^5_4O^8_8=13\times\overline{5\cdot52}=71\cdot76=4\times\underline{17\cdot94}$ obs. vol. $-17\cdot8-18\cdot0$.

Manganite is isomorphous with göthite and diaspore.

The molecular volumes of these bodies are as follows :—

Diaspore $=\overline{Al^2_2}H^1_2O^4_4=7\times\overline{5\cdot14}=\underline{35\cdot98}$ obs. vol. $=\underline{35\cdot98}$.

Manganite $=Mn^5_4H^2_4\overline{O^8_8}=15\times\overline{5\cdot40}=81=2\times\underline{40\cdot5}$ obs. vol. $=\underline{40\cdot5}$.

Göthite $=Fe^5_4H^2_4\overline{O^8_8}=15\times\overline{5\cdot40}=81=2\times\underline{40\cdot5}$ obs. vol. $=\underline{40\cdot5}$.

In diaspore, therefore, the aluminium stere dominates, but in manganese and göthite the oxygen stere $=\overline{5\cdot40}$.

All the other oxides of manganese contain the manganese as Mn^3_2, thus :—

Manganous oxide $=\overline{Mn^3_2}O^2_2=5\times\overline{5\cdot52}=2\times\underline{13\cdot80}$ obs. vol. $=\underline{13\cdot80}$.

Braunite " $=\overline{Mn^3_2}O^3_3=6\times\overline{5\cdot52}=\underline{33\cdot12}$ obs. vol. $=\underline{33\cdot12}$.

Hausmannite " $=\overline{Mn^9_6}O^8_8=17\times\overline{5\cdot52}=\underline{93\cdot82}=2\times\underline{46\cdot91}$ obs. vol. $=\underline{47\cdot10}$.

In the manganese silicates, the manganese has the condensation

Mn_2^3, and the silicic acid the same volume constitution as quartz, viz., $Si_1^2O_2^2$, thus:—

$$\text{Tephroite} = Mn_2^3Si_1^2\overline{O_4^4} = 9 \times \overline{5{\cdot}4} = \underline{48{\cdot}6} \text{ obs. vol.} = \underline{48{\cdot}6}.$$

$$\text{Paisbergite} = \overline{Mn_4^6}Ca_1^1Si_5^{10}O_{15}^{15} = 32 \times \overline{5{\cdot}52} = \underline{176{\cdot}64} \text{ obs. vol.} = \underline{176{\cdot}64}.$$

In the first of these minerals the oxygen stere dominates, whilst in the latter it is the manganese stere.

Hermann, examining a series of oxides having the form RO, finds that the volume of the oxygen in them=5, which he designates as its normal value. The volume (5) is probably correct, but why this particular volume should be dignified by the term normal, it is not so easy to see. The volume of a monatomic molecule of oxygen is the only one entitled to be called normal if it could be got at, and is probably=20. He then infers that the specific gravity of solid oxygen is $\frac{16}{5}=3{\cdot}2$. It is unnecessary to speculate on what is the specific gravity of solid oxygen, but it may be remarked, in passing, that solid oxygen cannot have less than two atoms in its molecule, and that its molecular volume is probably 20, which would give $\frac{32}{20}=1{\cdot}6$ as its probable specific gravity. Hermann then proceeds to assign this volume (5) to the oxygen of water, H_2O, the molecular volume of which=18, and then deducting (5) from (18) he obtains 13 for the volumes of the two hydrogen and 6·5 for a single atom of hydrogen. It is submitted that the tables which accompany this paper contain abundant evidence that oxygen contributes (10) to the molecular volume of water, and the hydrogen atoms (4) each. For in nearly a hundred compounds containing hydrogen, the hydrogen atom is never found with a volume greater than (4), but in a great number of cases with that volume. The next step is to determine the volume of nitrogen from a consideration of the density of fluid ammonia which is taken as ·629. Dividing the molecular weight of ammonia (17) by ·629 gives (27) as its molecular volume. Then deducting from (27) $3 \times 6{\cdot}5$ for the three hydrogen atoms, leaves 7·5 for the volume of nitrogen. The same observation may be applied to this determination as to the previous one, that hydrogen never has so great a volume as 6·5. According to the system of this paper, the molecular volume of ammonia is 24—Loschmidt makes it 23·5—the nitrogen contributing 12 and the three atoms of hydrogen (4) each, and therefore, though the density of liquid ammonia may be ·629 at a certain temperature, the probable specific gravity of solid ammonia is $\frac{17}{24}=\cdot708$. The density of liquid ammonia at $-10^\circ{\cdot}7$ C. has been found to be as high as ·650. By such methods as the above, and others, Hermann determines the normal volumes of the elements, but he supposes the non-metallic elements and the lighter metals capable of assuming other volumes than the normal ones in their compounds, though not so

the heavy metals. For instance, taking unity to represent the normal volume, oxygen may assume the following volumes :—$\frac{1}{2}$, 1, $1\frac{1}{3}$, $1\frac{1}{2}$, $1\frac{2}{3}$, 2 and 3; sulphur, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{7}{8}$, 1 and $1\frac{1}{2}$; and the halogens, $\frac{1}{3}$, $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{4}$, $\frac{7}{8}$, $1\frac{1}{4}$.

In conclusion, it may be remarked that the tables lend their chief support to proposition (3). Propositions (1) and (2) must be considered more hypothetical, but the writer wished to place them on record, because, if true, they would afford a physical interpretation to the fundamental numbers of column (IV) Table I. In proposition (1) also is to be found an explanation of the allotropism of the elements, carbon, silicon and phosphorus, based as it is upon the supposition that these allotropic forms contain a different number of atoms in the nucleus of their molecules with the same molecular volumes, and there are independent physical reasons, which render it not improbable that the accumulation of similar atoms in the nucleus of a molecule would not alter its volume, whatever be the law of force in action. The question is perhaps not altogether beyond the reach of direct experimental investigation. For if experiments on interdiffusion could be carried on at the temperature of gaseous mercury, the determination of the molecular volume of *monatomic* mercury, by the method of Loschmidt, would shed a very great deal of light on the subject.

Note.—Let V be the volume of any solid or liquid substance, W its weight, S its specific gravity, then

$$S=\frac{W}{V}.$$

The unit of volume being the volume of the unit of weight of the standard substance.

For distinctness we will take the hydrogen atoms as the unit of weight, and water at its greatest density as the standard substance. Then

$$\text{Volume of molecule of water}=\frac{\text{weight of molecule}}{\text{specific gravity of water}}=\frac{H_2O}{1}=18,$$

or the unit of volume is $\frac{1}{18}$ part of the volume of the molecule of water.

Suppose the substance to contain n molecules, then—

$$S=\frac{\frac{W}{n}}{\frac{V}{n}}.$$

Now $\frac{W}{n}$ is the weight of one molecule, and we may define $\frac{V}{n}$ as the volume of one molecule.

But
$$\frac{V}{n}=\frac{\text{volume of molecule of substance}}{\frac{1}{18}\text{ volume of molecule of water}}.$$

Consequently, the numerical value of $\frac{V}{n}$ would not be altered if we took for our definition of molecular volume any volume bearing a fixed proportion to the volume first taken as such definition. The numerator and denominator of the fraction (1) would both be increased or diminished in the same proportion. Now, inasmuch as the molecules of any substance will pack themselves as closely as their mutual repulsions will allow, it follows from geometry that the space $\frac{V}{n}$ is proportional to the sphere of repulsion of the molecule of the substance.

Hence we may define the volume of a molecule as the volume of its sphere of repulsion without affecting the equation.

$$\text{Specific gravity of substance}=\frac{\text{weight of molecule}}{\text{volume of molecule}}.$$

Table I.

Element.	Atomic weight.	Molecular weight.	Molecular or atomic volume.	Calculated sp. gr.	Observed sp. gr.
H	1	..	8		
O	16	..	20		
N	14	..	24		
F	19	..	24		
Cl.	35 ·5	..	45		
Br	80	..	88		
I.	127	I_5	128	4 ·961	4 ·950
C (diamond)	12	C_9	32	3 ·375	3 ·350
C (graphite)	,,	C_6	32	2 ·250	2 ·250
C (lamp-black)	,,	C_5	,,	1 ·875	1 ·885
B (adamantine)	11	B_7	28	2 ·750	2 ·680
Si (graphitoidal)	28 ·5	Si_6	70	2 ·443	2 ·490
Si (amorphous)	,,	Si_5	,,	2 ·035	2 ·000
P (red)	31	P_7	102	2 ·127	2 ·140
P (yellow)	,,	P_6	,,	1 ·823	1 ·830
P (white)	,,	P_5	,,	1 ·519	1 ·515
S	32	S_6	96	2 ·000	2 ·050
K.	39	K_2	90	·866	·865
Na	23	Na_2	48	·958	·970
Ba	137		92		
Sr.	87 ·5	Sr_2	70	2 ·500	2 ·500
Ca	40	Ca_2	50	1 ·600	1 ·600
Mg	24	Mg_2	27	1 ·777	1 ·750
Al	27 ·5	Al_3	32	2 ·578	2 ·600
Zr	89 ·6	Zr_3	66	4 ·073	4 ·150
Ag	108	Ag_4	43	10 ·047	10 ·428
Cd	112	Cd_4	52	8 ·619	8 ·600
Zn	65	Zn_4	37	7 ·027	6 ·8—7 ·2

Elements.	Atomic weight.	Molecular weight.	Molecular or atomic volume.	Calculated sp. gr.	Observed sp. gr.
Cu	63·5	Cu_4	29	8·760	8·800
Hg	2·00	Hg_4	58	13·793	13·590
Pb	207	Pb_4	74	11·200	11·445
Ti	50	Ti_6	58	5·173	5·300
Sn	118	Sn_4	66	7·151	7·280
Sb	122	Sb_4	72	6·777	6·700
Bi	208	Bi_4	84	9·904	9·830
Ni	59	Ni_4	29	8·138	8·500
Co	59	Co_4	29	8·138	8·500
As	75	As_6	76	5·921	5·900
Cr	52·5	Cr_6	45	7·000	7·014
Fe	56	Fe_6	43	7·814	7·800
Mn	55	Mn_6	43	7·697	7·0—8·0
Pt	197·4	Pt_6	56	21·150	21·150

Table II.—Oxides.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Barium oxide	BaO	$Ba'_4O'_4$	5·464	5·456
Strontium "	SrO	$Sr'_4O'_4$	4·600	4·611
Calcium "	CaO	$Ca'_4O'_4$	3·200	3·180
Magnesium "	MgO	$Mg'_4O'_4$	3·404	3·2—3·6
Zinc "	ZnO	$Zn'_4O'_4$	5·684	5·684
Cadmium "	CdO	$Cd'_4O'_4$	7·111	6·950
Cupric "	CuO	$Cu'_4O'_4$	6·490	6·500

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Mercuric oxide	HgO	$Hg'_4O'_4$	11·077	11·100
Lead ,,	PbO	$Pb'_4O'_4$	9·489	9·500
Potassium ,,	K_2O	$K'_6O'_4$	2·685	2·660
Sodium ,,	Na_2O	$Na'_6O'_4$	2·952	2·870
Silver ,,	Ag_2O	$Ag'_4O'_2$	7·365	7·250
Cuprous ,,	Cu_2O	$Cu'_4O'_2$	5·836	5·750
Mercurous ,,	Hg_2O	$Hg'_4O'_2$	10·666	10·680
Silicic dioxide (amorphous)	SiO_2	$Si'_4O'_4$	2·200	2·200
,, ,, (crystalline)	SiO_2	$Si'_4O'_8$	2·688	2·690
Titanium ,, (rutile)	TiO_2	$Ti'_4O'_8$	4·256	4·250
,, ,, (anatase)	TiO_2	$Ti'_4O'_6$	3·875	3·890
Zirconium ,,	ZrO_2	$Zr'_4O'_8$	5·655	5·624
,, ,,	ZrO_2	$Zr'_4O'_4$	4·588	4·35—4·90
Lead ,,	PbO_2	$Pb'_4O'_6$	9·497	9·500
Manganese ,,	MnO_2	$Mn'_4O'_6$	5·000	5·026
Stannic ,,	SnO_2	$Sn'_4O'_8$	6·976	6·960
Chromium trioxide	CrO_3	$Cr'_2O'_4$	2·680	2·674
Arsenic sesquioxide	As_2O_3	$As'_4O'_4$	3·733	3·738
Antimony ,,	Sb_2O_3	$Sb'_4O'_4$	5·725	5·778
Bismuth ,,	Bi_2O_3	$Bi'_4O'_4$	8·140	8·200
Cobalt ,,	Co_2O_3	$Co'_4O'_4$	5·627	5·600
,, ,,	Co_2O_3	$Co'_4O'_3$	4·811	4·814
Nickel ,,	Ni_2O_3	$Ni'_4O'_3$	4·811	4·814
Boron ,,	B_2O_3	$B'_2O'_6$	1·842	1·830
Aluminium ,,	Al_2O_3	$Al'_4O'_6$	3·953	3·950
Manganese ,,	Mn_2O_3	$Mn'_4O'_4$	4·331	4·325
Ferric ,,	FeO_3	$Fe'_4O'_6$	5·080	5·121
Antimony tetroxide	Sb_2O_4	$Sb'_4O'_8$	6·695	6·615
Antimonic oxide	Sb_2O_5	Sb_4O_8	6·680	6·600
Minium	Pb_3O_4	Pb_4O_4	9·073	9·080

Table III.—Fluorides.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Sodium fluoride	NaF	$Na'_6F'_3$	2.625	2·600
Potassium ,,	KF	$K'_6F'_3$	2·521	2·454
Calcium ,,	CaF_2	$Ca'_3F'_6$	3·162	3·162
Barium ,,	BaF_2	$Ba'_3F'_6$	4·526	4·580
Aluminium ,,	Al_2F_6	$Al'_4F'_6$	3·018	3·065
Hydro ammonic ,,	$(NH_4)HF_2$	$(NH'_4)_2H'_3F'_3$	1·221	1·211
Potassio titanic ,,	K_2TiF_6	$K'_4Ti'_6F'_6$	3·076	3·079*
Barium silicofluoride	$BaSiF_6$	$Ba'_3Si'_6F'_6$	4·213	4·279
Ammonium ,,	$(NH_4)_2SiF_6$	$(NH_4)'_2Si_6F'_6$	1·946	1·970
Sodium ,,	Na_2SiF_6	$Na'_6Si'_4F'_4$	2·710	2·754
Potassium ,,	K_2SiF_6	$K'_6Si'_4F'_4$	2·641	2·664
Ammonium stannofluoride	$(NH_4)_2SnF_6$	$(NH_4)'_2Sn'_6F'_6$	2·966	2·887
Potassium zircofluoride	K_2ZrF_6	$K'_4Zr'_6F'_6$	3·520	3·582
,, titanofluoride	$K_2TiF_6.H_2O$	$K'_6Ti'_3F'_6H'_4O'_2$	2·977	2·992
Copper silicofluoride	$(CuSiF_6)_2 13H_2O$	$Cu'_3Si'_3F'_6H'_4O'_2$	2·182	2·157

* In Clarke's "Constants of Nature," this is given as 2·079, but surely this is a misprint for 3·079; for it is highly improbable that the sp. gr. of K_2TiF_6 is less than that of its hydrate, $K_2TiF_6H_2O$ = 2·992, or of K_2SiF_6 = 2·664.

Table IV.

Chlorides.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
a. Simple Chlorides.				
Potassium chloride	KCl	$K'_4Cl'_3$	1·986	1·994
Sodium ,,	$NaCl$	$Na'_4Cl'_3$	2·166	2·148
Silver ,,	$AgCl$	$Ag'_4Cl'_3$	5·572	5·567
Lead ,,	$PbCl_2$	$Pb'_4Cl'_3$	5·732	5·742
Barium ,,	$BaCl_2$	$Ba'_4Cl'_3$	3·961	3·886
Strontium ,,	$SrCl_2$	$Sr'_3Cl'_3$	2·971	2·960
Calcium ,,	$CaCl_2$	$Ca'_3Cl'_3$	2·380	2·362
Mercuric ,,	$HgCl_2$	$Hg'_3Cl'_3$	5·493	5·420
Mercurous ,,	Hg_2Cl_2	$Hg'_3Cl'_3$	6·821	6·946
Ammonium ,,	$(H_4N)Cl$	$(H_4N)'_3Cl'_3$	1·589	1·578
Magnesium ,,	$MgCl_2$	Mg'_2Cl_3	2·183	2·177
Cupric ,,	$CuCl_2$	$Cu'_2Cl'_3$	3·022	3·054
Cuprous ,,	Cu_2Cl_2	Cu_2Cl_3	3·355	3·376
Zinc ,,	$ZnCl_2$	Zn_2Cl_3	2·804	2·753
Cobalt ,,	$CoCl_2$	$Co'_2Cl'_3$	2·921	2·937
Manganese ,,	$MnCl_2$	Mn'_2Cl_3	2·448	2·480
Ferrous ,,	$FeCl_2$	Fe_2Cl_3	2·467	2·529
b. Double Chlorides.				
Potassium zinochloride	K_2ZnCl_4	$K'_4Zn'_2Cl'_3$	2·307	2·297
Ammonium ,,	$(NH_4)_2ZnCl_4$	$(NH_4)'_2Zn'_2Cl'_3$	1·806	1·72 —1·879
Potassium platinochloride	K_2PtCl_6	$K'_6Pt'_4Cl'_3$	3·645	3·386—3·694
Ammonium ,,	$(NH_4)_2PtCl_6$	$(NH_4)'_3Pt_3Cl_3$	3·016	3·009

Table IV (*continued*).

c. Hydrated Chlorides.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Calcium chloride	$CaCl_2.6H_2O$	$Ca'_3Cl'_3H'_4O'_2$	1·676	1·680
Strontium ,,	$SrCl_2.6H_2O$	$Sr'_3Cl'_3H'_4O'_2$	1·941	1·921
Barium ,,	$BaCl_2.2H_2O$	$Ba'_4Cl'_3H'_4O'_2$	3·031	3·052
Cobaltous ,,	$CoCl_2.6H_2O$	$Co'_2Cl'_3H'_4O'_2$	1·852	1·840
Cupric ,,	$CuCl_2.2H_2O$	$Cu'_3Cl'_3H'_4O'_2$	2·518	2·535
Magnesium ,,	$MgCl_2.6H_2O$	$Mg'_2Cl'_3H'_4O'_2$	1·592	1·562
Stannous ,,	$SnCl_2.2H_2O$	$Sn'_3Cl'_3H'_4O'_2$	2·812	2·759
Platinic ,,	$PtCl_4.8H_2O$	$Pt'_2Cl'_3H'_4O'_2$	2·417	2·431
Potassium iron ,,	$K_2FeCl_4.2H_2O$	$K'_4Fe'_4Cl'_3H'_4O'_2$	2·170	2·162
,, copper ,,	$K_2CuCl_4.2H_2O$	$K'_6Cu'_2Cl'_3H'_4O_2$	2·411	2·410
Ammonium ,,	$(NH_4)_2CuCl_4.2H_2O$	$(NH_4)'_3Cu'_2Cl'_3H'_4O'_2$	1·984	1·977
Potassium tin ,,	$K_2SnCl_4.3H_2O$	$K'_6Sn'_3Cl'_3H'_4O_2$	2·545	2·514
Ammonium tin ,,	$(NH_4)_2SnCl_4.3H_2O$	$(NH_4)'_3Sn'_3Cl'_3H'_4O'_2$	2·169	2·104

Table V.

Bromides.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
a. Simple Bromides.				
Sodium bromide	$NaBr$	$Na'_4Br'_4$	3·029	3·011
Potassium ,,	KBr	$K'_4Br'_4$	2·674	2·672
Ammonium ,,	$(NH_4)Br$	$(NH_4)'_3Br'_4$	2·409	2·379
Silver ,,	$AgBr$	$Ag'_4Br'_4$	5·740	5·800
,, ,,	$AgBr$	$Ag'_6Br'_4$	6·445	6·425
Strontium ,,	$SrBr_2$	$Sr'_4Br'_4$	4·025	3·962
Lead ,,	$PbBr_2$	$Pb'_6Br'_4$	6·514	6·611
Zinc ,,	$ZnBr_2$	$Zn'_2Br'_4$	3·600	3·643
Cadmium ,,	$CdBr_2$	Cd'_4Br_4	4·771	4·712
Aluminium ,,	Al_2Br_6	$Al'_2Br'_6$	2·571	2·540
Potassium platinobromide	K_2PtBr_6	$K'_4Pt'_2Br'_6$	4·693	4·680
Ammonium zinc bromide	$(NH_4)_2ZnBr_4$	$(NH_4)'_2Zn'_2Br'_4$	2·598	2·625
Potassium stannobromide	K_2SnBr_6	$K'_6Sn'_4Br'_4$	3·787	3·783
b. Hydrated Bromides.				
Barium bromide	$BaBr_2 3H_2O$	$Ba'_4Br'_6H'_4O'_2$	3·721	3·690
,, platinobromide	$BaPtBr_6 10H_2O$	$Ba'_4Pt'_4Br'_6H'_4O_2$	3·724	3·713
Phosphorus sulphobromide	$PSBr_3H_2O$	$P'_4S'_3Br_6H'_4O'_2$	2·771	2·793

Table VI.

Iodides.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Sodium iodide	NI	$Na'_4I'_4$	3·410	3·450
Potassium ,,	KI	$K'_4I'_4$	3·046	3·056
Ammonium ,,	$(NH_4)I$	$(NH_4)'_2I'_4$	2·417	2·498
Silver ,,	AgI	$Ag'_4I'_4$	5·500	5·500
Strontium ,,	SrI_2	$Sr'_6I'_4$	4·510	4·415
Barium ,,	BaI_2	$Ba'_6I'_4$	4·949	4·917
Lead ,,	PbI_2	$Pb'_6I'_4$	6·040	6·021
Mercurous ,,	HgI	$Hg'_6I'_4$	7·848	7·750
Mercuric ,,	HgI_2	$Hg'_6I'_4$	6·163	6·270
Arsenic ,,	AsI_3	$As'_2I'_6$	4·448	4·390
Antimony ,,	SbI_3	$Sb'_2I'_6$	5·005	5·010
Bismuth ,,	BiI_3	$Bi'_2I'_6$	5·555	5·652
Potassium platinoiodide	K_2PtI_6	$K'_4Pt'_2I'_6$	5·161	5·154
Ferrous iodide	FeI_24H_2O	$Fe'_3I'_4H'_4O'_2$	2·843	2·873

Table VII.

Cyanides and Cyanates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Potassium cyanide	KCy	$K'_6Cy'_2$	1·512	1·520
Silver ,,	$AgCy$	$Ag'_3(Cy)_3$	4·060	3·943
Potassium cyanate	$KCyO$	$K'_6Cy'_3O_4$	2·095	2·047
Silver ,,	$AgCyO$	$Ag'_3Cy'_3O'_4$	3·947	4·004
Sodium ferrocyanide	$Na_4Cy_6Fe12H_2O$	$Na'_3Cy'_3Fe'_2H'_4O'_2$	1·455	1·458
Potassium ,,	$K_4Cy_6Fe3H_2O$	$K'_6Cy'_3Fe'_2H'_4O'_2$	1·860	1·860
,, ferricyanide	K_3Cy_6Fe	$K'_6Cy'_3Fe'_2$	1·843	1·845
,, cobalticyanide	K_3Cy_6Co	$K'_6Cy'_3Co'_2$	1·936	1·906
Barium platinocyanide	$BaCy_4Pt$	$Ba'_2Cy'_3Pt'_2$	2·969	3·054
Potassium sulphocyanide	$KCyS$	$K'_6Cy'_3S'_6$	1·953	1·906
,, manganidcyanide	K_3Cy_6Mn	$K'_6Cy'_3Mn'_2$	1·832	1·821

Table VIII.

Sulphides.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Sodium sulphide	Na_2S	$Na'_6S'_6$	2·438	2·471
Oldhamite	CaS	$Ca'_4S'_6$	2·526	2·580
Lead monosulphide	PbS	$Pb'_4S'_6$	6·927	6·923
Mercury sulphide	HgS	$Hg'_4S'_6$	7·606	7·552
,, ,,	HgS	$Hg'_6S'_6$	9·027	8·998
Copper ,,	CuS	$Cu'_3S'_6$	3·739	3·800
,, ,,	CuS	$Cu'_6S'_6$	4·584	4·636
Zinc ,,	ZnS	$Zn'_3S'_8$	3·986	3·980
Cadmium ,,	CdS	$Cd'_3S'_8$	4·909	4·900
Tin ,,	SnS	$Sn'_4S'_8$	5·263	5·267
Cobalt ,,	CoS	$Co'_6S'_8$	5·407	5·450
Iron ,,	FeS	$Fe'_8S'_8$	5·008	5·035
Manganese disulphide	MnS_2	$Mn'_4S'_8$	3·424	3·463
Tin ,,	SnS_2	$Sn'_4S'_8$	4·494	4·415
Cobalt ,,	CoS_2	$Co'_6S'_8$	4·266	4·269
Arsenic ,,	As_2S_2	$As'_4S'_8$	3·452	3·4—3·6
Bismuth ,,	Bi_2S_2	$Bi'_4S'_8$	7·272	7·290
Arsenic trisulphide	As_2S_3	$As'_4S'_8$	3·324	3·400
Antimony ,,	Sb_2S_3	Sb'_4S_8	4·662	4·641

Table IX.

Sulphates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
a. Simple Sulphates.				
Potassium sulphate	K_2SO_4	$K'_6S'_6O_4$	2·636	2·640
Sodium ,,	Na_2SO_4	$Na'_6S'_6O'_4$	2·730	2·730
Barium ,,	$BaSO_4$	$Ba'_6S'_6O'_4$	4·568	4·590
Strontium ,,	$SrSO_4$	$Sr'_6S'_6O'_4$	3·850	3·900
Calcium ,,	$CaSO_4$	$Ca'_6S'_6O'_4$	3·068	3·100
Mercuric ,,	$HgSO_4$	$Hg'_6S'_6O'_4$	6·481	6·466
Lead ,,	$PbSO_4$	$Pb'_6S'_6O'_4$	6·269	6·257
Mercurous ,,	Hg_2SO_4	$Hg'_4S'_6O'_4$	7·630	7·560
Silver ,,	Ag_2SO_4	$Ag'_4S'_6O'_4$	5·426	5·425
Copper ,,	$CuSO_4$	$Cu'_4S'_6O'_4$	3·683	3·631
Cobalt ,,	$CoSO_4$	$Co'_4S'_6O'_4$	3·583	3·531
Ammonium ,,	$(NH_4)_2SO_4$	$(NH_4)'_3S'_6O'_4$	1·800	1·771
Zinc ,,	$ZnSO_4$	$Zn'_3S'_6O'_4$	3·331	3·400
Magnesium ,,	$MgSO_4$	$Mg'_3S'_6O'_4$	2·666	2·648
Aluminium ,,	$Al_2(SO_4)_3$	$Al'_4S'_6O'_4$	2·766	2·740
b. Double Sulphates.				
Potassium hydrogen sulphate	$KHSO_4$	$K'_6H'_2S'_6O'_4$	1·474	1·475
,, zinc ,,	$K_2Zn(SO_4)_2$	$K'_6Zn'_2S'_6O'_4$	2·780	2·816
,, copper ,,	$K_2Cu(SO_4)_2$	$K'_6Cu'_2S'_6O'_4$	2·862	2·797
,, magnesium ,,	$K_2Mg(SO_4)_2$	$K'_6Mg'_3S'_6O'_4$	2·649	2·676
,, nickel ,,	$K_2Ni(SO_4)_2$	$K'_6Ni'_3S'_6O'_4$	2·944	2·897
,, sodium ,,	$K_3Na(SO_4)_2$	$K'_6Na'_6S'_6O'_4$	2·656	2·668
,, manganese ,,	$K_2Mn(SO_4)_2$	$K'_6Mn'_6S'_6O'_4$	2·965	3·008

Table IX (*continued*).

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Ammonium aluminium sulphate	$(NH_4)Al(SO_4)_2$	$(NH_4)'_2Al'_2S'_6O'_4$	2·035	2·039
,, zinc ,,	$(NH_4)_2Zn(SO_4)_2$	$(NH_4)'_3Zn'_2S'_6O'_4$	2·292	2·222
Calcium sodium ,,	$CaNa_2(SO_4)_2$	$Ca'_4Na'_6S'_6O'_4$	2·766	2·767
,, barium ,,	$CaBa_3(SO_4)_4$	$Ca'_3Ba'_3S'_6O'_4$	3·330	3·2—3·4
c. Hydrated Sulphates.				
Sodium sulphate	$Na_2SO_4.10H_2O$	$Na'_2S'_6O'_4H'_4O'_2$	1·437	1·445
Ammonium ,,	$(NH_4)_2SO_4.H_2O$	$(NH_4)'_3S'_6O'_4H'_4O'_2$	1·719	1·72—1·73
Copper ,,	$CuSO_4.5H_2O$	$Cu'_4S'_6O'_4H'_4O'_2$	2·203	2·200
Manganese ,,	$MnSO_4.5H_2O$	$Mn'_4S'_6O'_4H'_4O'_2$	2·060	2·087
Magnesium ,,	$MgSO_4.7H_2O$	$Mg'_3S'_6O'_4H'_4O'_2$	1·720	1·751
Zinc ,,	$ZnSO_4.7H_2O$	$Zn'_3S'_6O'_4H'_4O'_2$	1·961	1·957
Nickel ,,	$NiSO_4.7H_2O$	$Ni'_3S'_6O'_4H'_4O'_2$	1·955	1·931
Cobalt ,,	$CoSO_4.7H_2O$	$Co'_3S'_6O'_4H'_4O'_2$	1·955	1·924
Iron ,,	$FeSO_4.7H_2O$	$Fe'_3S'_6O'_4H'_4O'_2$	1·874	1·884
Cadmium ,,	$CdSO_4.H_2O$	$Cd'_2S'_6O'_4H'_4O'_2$	2·973	2·939
,, ,,	$Cd_3(SO_4)_3.8H_2O$	$Cd'_4S'_6O'_4H'_4O'_2$	3·000	3·050
Iron ,,	$Fe_2(SO_4)_3.9H_2O$	$Fe'_2S'_6O'_4H'_4O'_2$	2·029	2·0—2·1
Aluminium ,,	$Al_2(SO_4)_3.18H_2O$	$Al'_2S'_6O'_4H'_4O'_2$	1·702	1·671

Table IX (*continued*).

d. Hydrated Double Sulphates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Ammonium sodium sulphate	$(NH_4)NaSO_4 2H_2O$	$(NH_4)'_3Na'_2S'_6O'_4H'_4O'_2$	1·621	1·630
,, magnesium ,,	$(NH_4)_2Mg(SO_4)_2.6H_2O$	$(NH_4)'_3Mg_2S'_6O'_4H'_4O'_3$	1·740	1·721
,, copper ,,	$(NH_4)_2Cu(SO_4)_2.6H_2O$	$(NH_4)'_3Cu'_2S'_6O'_4H'_4O'_2$	1·924	1·931
,, zinc ,,	$(NH_4)_2Zn(SO_4)_2.6H_2O$	$(NH_4)_3Zn'_2S'_6O'_4H'_4O'_2$	1·893	1·897
,, cadmium ,,	$(NH_4)_2Cd(SO_4)_2 6H_2O$	$(NH_4)_3Cd'_2S'_6O'_4H'_4O'_2$	2·043	2·073
,, nickel ,,	$(NH_4)_2Ni(SO_4)_2 6H_2O$	$(NH_4)'_3Ni'_2S'_6O'_4H'_4O'_2$	1·905	1·915
,, cobalt ,,	$(NH_4)_2Co(SO_4)_2.6H_2O$	$(NH_4)'_3Co'_2S'_6O'_4H'_4O'_2$	1·905	1·873
,, iron ,,	$(NH_4)_2Fe(SO_4)_2 6H_2O$	$(NH_4)'_3Fe'_2S'_6O'_4H'_4O'_2$	1·825	1·830
Potassium magnesium ,,	$K_2Mg(SO_4)_2 6H_2O$	$K'_6Mg'_3S'_6O'_4H'_4O'_2$	2·061	2·076
,, copper ,,	$K_2Cu(SO_4)_2 6H_2O$	$K'_6Cu'_3S'_6O'_4H'_4O'_2$	2·255	2·244
,, zinc ,,	$K_2Zn(SO_4)_2 6H_2O$	$K'_6Zn'_3S'_6O'_4H'_4O'_2$	2·234	2·240
,, cobalt ,,	$K_2Co(SO_4)_2 6H_2O$	$K'_6Co'_2S'_6O'_4H'_4O'_2$	2·179	2·154
,, cadmium ,,	$K_2Cd(SO_4)_2 6H_2O$	$K'_6Cd'_4S'_6O'_4H'_4O'_2$	2·462	2·438
,, iron ,,	$K_2Fe(SO_4)_2 6H_2O$	$K'_6Fe'_4S'_6O'_4H'_4O'_2$	2·205	2·202
Sodium alum	$AlNa(SO_4)_2 12H_2O$	$Al'_2Na'_2S'_6O'_4H'_4O'_2$	1·637	1·641
Ammonium ,,	$Al(NH)_4(SO_4)12H_2O$	$Al'_2(NH_4)_3S_6O'_4H'_4O'_2$	1·651	1·653
Potassium ,,	$AlK(SO_4)_2 12H_2O$	$Al'_2K'_6S'_6O'_4H'_4O'_2$	1·751	1·753
,, chrome alum	$CrK(SO_4)_2 12H_2O$	$Cr'_3K'_6S'_6O'_4H'_4O'_2$	1·850	1·848
Ammonium ,, ,,	$Cr(NH_4)(SO_4)_2 12H_2O$	$Cr'_3(NH_4)'_3S'_6O'_4H'_4O'_2$	1·748	1·738
,, iron ,,	$Fe(NH_4)(SO_4)_2 12H_2O$	$Fe'_2(NH_4)'_3S'_6O'_4H'_4O'_2$	1·714	1·712
Magnesium iron sulphate	$MgFe(SO_4)_2 14H_2O$	$Mg'_2Fe'_2S'_6O'_4H'_4O'_2$	1·730	1·733
,, copper ,,	$MgCu(SO_4)_2.14H_2O$	$Mg'_2Cu'_3S'_6O'_4H'_4O'_2$	1·825	1·813
,, zinc ,,	$MgZn(SO_4)_2 14H_2O$	$Mg'_2Zn'_3S'_6O'_2H'_4O'_2$	1·814	1·817
,, cadmium ,,	$MgCd(SO_4)_2 14H_2O$	$Mg'_2Cd'_4S'_6O'_4H'_4O'_2$	1·970	1·983

Table X.

Nitrates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
a. Simple Nitrates.				
Sodium nitrate	$NaNO_3$	$Na'_6N'_2O'_3$	2·125	2·180
Potassium ,,	KNO_3	$K'_6N'_2O'_3$	2·148	2·143
Ammonium ,,	$(NH_4)NO_3$	$(NH_4)'_3N'_2O'_3$	1·579	1·579
,, ,,	,,	$(NH_4)'_4N'_2O'_3$	1·739	1·737
Silver ,,	$AgNO_3$	$Ag'_6N'_2O'_3$	4·340	4·336
Calcium ,,	$Ca(NO_3)_2$	$Ca'_6N'_2O'_3$	2·267	2·240
Strontium ,,	$Sr(NO_3)_2$	$Sr'_6N'_2O'_3$	2·807	2·857
Barium ,,	$Ba(NO_3)_2$	$Ba'_6N'_2O'_3$	3·289	3·284
Lead ,,	$Pb(NO_3)_2$	$Pb'_6N'_2O'_3$	4·336	4·340
b. Hydrated Nitrates.				
Calcium nitrate	$CaN_2O_6.4H_2O$	$Ca'_6N'_2O'_3H'_4O'_2$	1·843	1·78—1·90
Strontium ,,	$SrN_2O_6.5H_2O$	$Sr'_6N'_2O'_3H'_4O'_2$	2·069	2·113
Manganese ,,	$MnN_2O_6.6H_2O$	$Mn'_4N'_2O'_3H'_4O'_2$	1·836	1·819
Cobalt ,,	$CoN_2O_6.6H_2O$	$Co'_3N'_2O'_3H'_4O'_2$	1·845	1·830
Iron ,,	$Fe_2(NH_3)_6.18H_2O$	$Fe'_3N'_2O'_3H'_4O'_2$	1·692	1·683
Bismuth ,,	$BiN_2O_9.5H_2O$	$Bi'_6N'_2O'_3H'_4O'_2$	2·688	2·736

Table XI.

Chromates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
a. Simple Chromates.				
Potassium chromate	K_2CrO_4	$K'_6Cr'_2O'_4$	2·682	2·682
Silver ,,	$AgCrO_4$	$Ag'_6Cr'_2O'_4$	5·850	5·770
Barium ,,	$BaCrO_4$	$Ba'_4Cr'_2O'_4$	3·870	3·900
Lead ,,	$PbCrO_4$	$Pb'_6Cr'_2O'_4$	5·900	5·950
Potassium dichromate	$K_2Cr_2O_7$	$K'_6Cr'_2O'_4$	2·682	2·680
Ammonium ,,	$(NH_4)_2Cr_2O_7$	$(NH_4)'_4Cr'_2O'_4$	2·343	2·367
Potassium trichromate	$K_2Cr_3O_{10}$	$K'_6Cr'_2O'_4$	2·681	2·655
Phœnicochroit	$Pb_3Cr_2O_9$	$Pb'_6Cr'_2O'_4$	5·980	6·000
b. Hydrated Chromates.				
Copper chromate	$CuCrO_45H_2O$	$Cu'_4Cr'_2O'_4H'_4O'_2$	2·254	2·262
Zinc ,,	$ZnCrO_47H_2O$	$Zn'_4Cr'_2O'_4H'_4O'_2$	2·053	2·096
Magnesium ,,	$MgCrO_47H_2O$	$Mg'_2Cr'_2O'_4H'_4O'_2$	1·730	1·750

Table XII.

Phosphates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
		a. Simple Phosphates.		
Trisilver phosphate	Ag_3PO_4	$Ag'_6P'_6O'_4$	7·163	7·300
Lead ,,	$Pb_3(PO_4)_2$	$Pb'_6P'_6O'_4$	7·306	7·208
Silver pyrophosphate	$Ag_4P_2O_7$	$Ag'_4P'_6O'_4$	5·410	5·306
Ammonium dihydrogen phosphate	$(NH_4)H_2PO_4$	$(NH_4)'_3H'_2P'_6O'_4$	1·805	1·758
Diammonium hydrogen ,,	$(NH_4)_2HPO_4$	$(NH_4)'_3H'_2P'_6O'_4$	1·685	1·678
		b. Hydrated Orthophosphates.		
Trisodium phosphate	$Na_3PO_4.12H_2O$	$Na'_6P'_6O'_4H'_4O'_2$	1·659	1·622
Sodium pyrophosphate	$Na_4P_2O_7 10H_2O$	$Na'_6P'_6O'_4H'_4O_2$	1·850	1·836
Disodium hydrogen phosphate	$Na_2HPO_4 12H_2O$	$Na'_4H'_4P'_6O'_4H'_4O'_2$	1·549	1·550
Dihydrogen sodium ,,	$NaH_2PO_4H_2O$	$Na'_4H'_4P'_6O'_4H'_4O'_2$	2·059	2·040
Triple phosphate No. I	$(NH_4)NaHPO_4 4HO$	$(NH_4)'_2Na'_4H'_4P'_6O'_4H'_4O'_2$	1·549	1·554
,, ,, No. II	$KNaHPO_4.7H_2O$	$K'_4Na'_4H'_4P'_6O'_4H'_4O'_2$	1·657	1·671
Struvite	$(NH_4)MgPO_4.6HO_2$	$(NH_4)'_3Mg'_3P'_6O'_4H'_4O'_2$	1·650	1·650
Berlinite	$Al_4(PO_4)_4.H_2O$	$Al'_4P'_6O'_4H'_4O'_2$	2·620	2·640

Table XIII.

Arsenites and Arsenates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
	a. Simple Arsenites and Arsenates.			
Lead arsenite	$Pb(AsO_2)_2$	$Pb'_6As'_4O'_4$	5·985	5·850
Native nickel arsenate	$Ni_3(AsO_4)_2$	$Ni'_6As'_4O'_4$	4·919	4·982
Potassium „	KH_2AsO_4	$K'_4H'_4As'_4O'_4$	2·748	2·638
Ammonium „	$(NH_4)H_2AsO_4$	$(NH_4)'_2H'_4As'_4O_4$	2·240	2·249
	b. Hydrated Arsenates.			
Sodium dihydrogen arsenate	$NaH_2AsO_4H_2O$	$Na'_4H'_2As'_4O'_4H'_4O'_2$	2·494	2·535
Disodium hydrogen „	$Na_2HAsO_4.7H_2O$	$Na'_4H'_2As'_4O'_4H'_4O'_2$	1·891	1·871
„ „ „	$Na_2HAsO_4.12H_2O$	$Na'_4H'_2As'_4O'_4H'_4O'_2$	1·711	1·736
Trisodium arsenate	$Na_3AsO_4.12H_2O$	$Na'_6As'_4O'_4H'_4O'_2$	1·835	1·804
Triple arsenate No. I	$(NH_4)NaHAsO_4.4H_2O$	$(NH_4)'_2Na'_4H'_4As'_4O'_4H'_4O'_2$	1·846	1·838
„ „ No. II	$KNaHAsO_4.7H_2O$	$K'_4Na'_4H'_4As'_4O'_4H'_4O'_2$	1·890	1·884
Hoernesite	$Mg_3(AsO_4)_2.8H_2O$	$Mg'_6As'_4O'_4H'_4O'_2$	2·427	2·474
Erythrite	$Co_3(AsO_4)_8.8H_2O$	$Co'_6As'_4O'_4H'_4O'_2$	2·924	2·948
Scorodite	$Fe_2(AsO_4)_2.4H_2O$	$Fe'_6As'_4O'_4H'_4O'_2$	3·115	3·110

Table XIV.

Borates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Sodium diborate	$Na_2B_4O_7$	$Na'_4B'_4O'_4$	2·322	2·367
,, ,,	$Na_2B_4O_7.5H_2O$	$Na'_4B'_4O'_4H'_4O'_2$	1·859	1·815
,, ,,	$Na_2B_4O_7 10H_2O$	$Na'_4B'_4O'_4H'_4O'_2$	1·683	1·692
Lead ,, borate	PbB_2O_4	$Pb'_4B'_4O'_4$	5·580	5·598
,, hydrogen ,,	$PbHB_3O_6$	$Pb'_6H'_4B'_4O'_4$	5·208	5·235
Magnesium ,,	$Mg_3B_2O_6$	$Mg'_4B'_4O'_4$	2·988	2·987

Table XV.

Chlorates and Bromates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Sodium chlorate	$NaClO_6$	$Na'_4Cl'_3O'_4$	2·535	2·467
Potassium ,,	$KClO_3$	$K'_4Cl'_3O'_4$	2·333	2·326
Lead ,,	$Pb(Cl_2O_3)_2.H_2O$	$Pb'_6Cl'_3O'_4H'_4O'_2$	3·981	3·989
Mercury ,,	$Hg_2Cl_2O_7H_2O$	$Hg'_3Cl'_3O'_4H'_4O'_2$	5·107	5·151
Sodium bromate	$NaBrO_3$	$Na'_6Br'_4O'_4$	3·355	3·339
Potassium ,,	$KBrO_3$	$K'_6Br'_4O'_4$	3·211	3·218
Magnesium ,,	$Mg(BrO_3)_2 6H_2O$	$Mg'_2Br'_4O'_4H'_4O'_2$	2·262	2·289

Table XVI.

Silicates and Titanates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
a. Simple Silicates and Titanates.				
Wollastonite	$CaSiO_3$	$Ca'_3Si'_4O'_8$	2·800	2·805
Rhodonite	$MnSiO_3$	$Mn'_4Si'_4O'_8$	3·678	3·630
Grünerite	$FeSiO_3$	$Fe'_4Si'_4O'_8$	3·706	3·713
Enstatite	$MgSiO_3$	$Mg'_4Si'_4O'_8$	3·165	3·130
Tephroite	Mn_2SiO_4	$Mn'_4Si'_4O'_8$	4·132	4·120
Fayalite	Fe_2SiO_4	$Fe'_4Si'_4O'_8$	4·173	4·138
Willemite	$Zn_2Si_2O_4$	$Zn'_4Si'_4O'_8$	3·922	3·935
Olivine	Mg_2SiO_4	$Mg'_4Si'_4O'_8$	3·426	3·440
Andalusite	Al_2SiO_5	$Al'_3Si'_4O'_8$	3·185	3·154
„ cyanite	Al_2SiO_5	$Al'_4Si'_4O'_8$	3·554	3·480—3·680
Zircon	$ZrSiO_4$	$Zr'_4Si'_4O'_8$	4·136	
Calcium titanate	$CaTiO_3$	$Ca'_4Ti'_4O'_8$	4·000	4·000
Magnesium „	$MgTiO_3$	$Mg'_3Ti'_4O'_8$	3·935	3·910
b. Double Silicates.				
Felspar	$KAlSi_3O_8$	$K'_4Al'_2Si'_4O'_8$	2·522	2·53—2·59
Albite	$NaAlSi_3O_8$	$Na'_4Al'_2Si'_4O'_8$	2·627	2·54—2·64
Batrachite	$CaMg(SiO_3)_2$	$Ca'_4Mg'_3Si'_4O'_8$	3·034	3·033
Monticellite	$CaMg(SiO_3)_2$	$Ca'_6Mg'_3Si'_4O'_8$	3·222	3·245—3·275
Leucite	$KAl(SiO_3)_2$	$K'_4Al'_2Si'_4O'_8$	3·482	2·45—2·5

Table XVII.

Carbonates.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
	a. Simple Carbonates.			
Barium carbonate	$BaCO_3$	$Ba'_4C'_4O'_4$	4·283	4·301
Strontium ,,	$SrCO_3$	$Sr'_4C'_4O'_4$	3·642	3·626
Calcium ,,	$CaCO_3$	$Ca'_4C'_4O'_4$	2·817	2·815
Lead ,,	$PbCO_3$	$Pb'_4C'_4O'_4$	6·433	6·430
Silver ,,	Ag_2CO_3	$Ag'_4C'_4O'_4$	6·202	6·080
	b. Simple Carbonates.			
Sodium carbonate	Na_2CO_3	$Na'_4C'_8O'_4$	2·469	2·466
Potassium ,,	K_2CO_3	$K'_4C'_8O'_4$	2·156	2·103—2·267
Ferric ,,	$FeCO_3$	$Fe'_4C'_8O'_4$	3·891	3·872
Zinc ,,	$ZnCO_3$	$Zn'_4C'_8O'_4$	4·424	4·420
Magnesium ,,	$MgCO_3$	$Mg'_3C'_8O'_4$	3·000	3·017
	c. Double Carbonates.			
Barytocalcite	$CaBa(CO_3)_2$	$Ca'_4Ba'_4C'_4O'_4$	3.666	3·660
Manganocalcite	$CaMn_2(CO_3)_3$	$Ca'_4Mn'_3C'_4O'_4$	3·000	3·037
Dolomite	$CaMg(CO_3)_2$	$Ca'_4Mg'_4C'_4O'_4$	2·819	2·845
Pistomesite	$FeMg(CO_3)_2$	$Fe'_4Mg'_3C'_8O'_4$	3·463	3·427
Mesitite	$FeMg_2(CO_3)_3$	$Fe'_4Mg'_3C'_8O'_4$	3·311	3·349
	d. Hydrated Double Carbonates			
Sodium carbonate	$Na_2CO_3H_2O$	$Na'_2C'_8O'_4H'_4O'_2$	1·531	1·5—1·6
Calcium ,,	$CaCO_3.5H_2O$	$Ca'_4C'_4O'_4H'_4O'_2$	1·800	1·783
Sodium potassium ,,	$KNaCO_312H_2O$	$K'_6Na'_6C'_8O'_4H'_4O'_2$	1·609	1·608
Gay-lussite	$CaNa_2(CO_3)_25H_2O$	$Ca'_4Na'_4C'_4O'_4H'_4O'_2$	1·941	1·950
Hydrodolomite	$CaMg_2(CO_3)_3H_2O$	$Ca'_3Mg'_4C'_4O'_4H'_4O'_2$	2·535	2·495

Table XVIII.

Metallic Salts of Organic Acids.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
a. Oxalates.				
Potassium oxalate	$K_2C_2O_4H_2O$	$K'_4C'_8O'_4H'_4O'_2$	2·114	2·104
Ammonium ,,	$(NH_4)_2C_2O_4H_2O$	$(NH_2)'_2C'_8O'_4H'_4O'_2$	1·450	1·461
Hydrogen sodium ,,	$NaHC_2O_4H_2O$	$Na'_4H'_4C'_8O'_4H'_4O'_2$	2·321	2·315
Potassium quadroxalate	$KH_3(CO_4)_22H_2O$	$K'_2H'_2C'_8O'_4H'_4O'_2$	1·802	1·817
Hydrogen ammonium oxalate	$(NH_4)HC_2O_4.H_2O$	$(NH_4)'_2H'_4C'_4O'_4H'_4O'_2$	1·562	1·563
,, potassium ,,	KHC_2O_4	$K'_4H'_2C'_4O'_4$	2·080	2·088
Potassium copper ,,	$K_2CuC_4O_8.2H_2O$	$K'_4Cu'_3C'_4O'_4H'_4O'_2$	2·285	2·288
Ammonium ,, ,,	$(NH_4)_2Cu(C_2O_4)_22H_2O$	$(NH_4)'_2Cu'_4C'_4O'_4H'_4O'_2$	1·908	1·923
Whewellite	CaC_2O_4	$Ca'_4C'_4O'_4$	2·666	2·50—2·75
b. Acetates.				
Sodium acetate	$NaC_2H_3O_2$	$Na'_4C'_4H'_3O'_2$	1·464	1·421
,, ,,	$NaC_2H_3O_26H_2O$	$Na'_6C'_4H'_3O'_2H'_4O'_2$	1·400	1·400
Silver ,,	$AgC_2H_3O_2$	$Ag'_4C'_4H'_3O'_2$	3·050	3·128
Lead ,,	$Pb(C_2H_3O_2)_2.3H_2O$	$Pb'_3C'_4H'_3O'_2H'_4O'_2$	2·471	2·496
Barium ,,	$Ba(C_2H_3O_2)_2H_2O$	$Ba'_4C'_4H'_3O'_2H'_4O'_2$	2·184	2·190
Zinc ,,	$Zn(C_2H_3O_2)_23H_2O$	$Zn'_4C'_4H'_3O'_2H'_4O'_2$	1·701	1·717
c. Tartrates.				
Sodium tartrate	$Na_2C_4H_4O_64H_2O$	$Na'_4C'_4H'_4O'_4H'_4O'_2$	1·773	1·794
Potassium ,,	$K_2C_4H_4O_6$	$K'_4C'_4H'_4O'_4$	1·965	1·975
Hydrogen potassium ,,	$KHC_4H_4O_6$	$K'_4H'_2C'_4H'_4O'_4$	1·948	1·943
,, ammonium ,,	$(NH_4)HC_4H_4O_6$	$(NH_4)'_2H'_4C'_4H'_4O'_4$	1·670	1·680
Sodium potassium ,,	$NaKC_4H_4O_64H_2O$	$Na'_4K'_4C'_4H'_4O'_4H'_4O'_2$	1·757	1·767
,, ammonium ,,	$(NH_4)NaC_4H_4O_64H_2O$	$(NH_4)'_2Na'_4C'_4H'_4O'_4H'_4O'_2$	1·572	1·576

Table XIX.

Organic Compounds.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Naphthalene	$C_{10}H_8$	$C'_4H'_2$	1·143	1·153
Anthracene	$C_{14}H_{10}$	$C'_4H'_2$	1·171	1·147
Paraffin	$X(CH_2)$	$X(C'_4H'_2)$	0·875	0·870
Caoutchouc	$X(C_5H_8)$	$X(C'_4H'_2)$	0·944	0·92—·906
Succinic acid	$C_4H_6O_4$	$C'_4H'_2O'_4$	1·552	1·552
Essence of aniseed	$C_{10}H_{12}O$	$C'_4H'_2O'_2$	1·072	1·073
Camphor	$C_{10}H_{16}O$	$C'_4H'_2O'_2$	0·987	0·996
Starch	$X(C_6H_{10}O_5)$	$X(C'_4H'_3O'_3)$	1·500	1·500
Sugar	$C_{12}H_{22}O_{11}$	$C'_4H'_4O'_3$	1·603	1·606
Perchlorinated ether	$C_4Cl_{10}O$	$C'_2Cl'_3O'_4$	1·913	1·900
Trichloracetic acid	$HC_2Cl_3O_2$	$H'_2C'_2Cl'_3O'_2$	1·618	1·617
Urea	CH_4N_2O	$C'_4H'_2N'_4O'_2$	1·304	1·300

Table XX.

Ammonio Compounds.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Cadmium ammonio chloride	$CdCl_2 2NH_3$	$Cd'_3Cl'_3N'_2H'_4$	2·605	2·632
Pupureo cobalt chloride	$Co_2Cl_6 10NH_3$	$CO'_6Cl'_3N'_2H'_4$	1·800	1·802
Luteo " "	$Co_2Cl_6 12NH_3$	$CO'_6Cl'_3N'_2H'_4$	1·706	1·701
Copper ammonio " 1st	$CuCl_2.2NH_3$	$Cu'_3Cl'_3N'_2H'_4$	2·225	2·194
" " " 2nd	$CuCl_2 4NH_3H_2O$	$Cu'_2Cl'_3N'_2H'_4H'_4O'_2$	1·689	1·672
Silver " sulphate	$Ag_2SO_4 4NH_3$	$Ag'_4S'_6O'_4N'_2H'_4$	2·933	2·918
" " chromate	$Ag_2CrO_4 4NH_3$	$Ag'_6Cr'_2O'_4N'_2H'_4$	3·108	3·063
Copper " sulphate	$CuSO_4 2NH_3$	$Cu'_4S'_6O'_4N'_2H'_4$	2·441	2·476
" " "	$CuSO_4 4NH_3H_2O$	$Cu'_2S'_6O'_4N'_2H'_4H'_4O'_2$	1·798	1·790
" " "	$CuSO_4 2NH_3 3H_2O$	$Cu'_2S'_6O'_4N'_2H'_4H'_4O'_2$	1·926	1·950

Table XXI.

Miscellaneous Compounds.

Substance.	Molecular weight.	Molecular volume.	Calculated sp. gr.	Observed sp. gr.
Cyanogen iodide	CyI	$Cy'_3I'_2$	1·850	1·850
Chromic chloride	Cr_2Cl_6	$Cr'_6Cl'_3$	3·028	3·030
,, chromate	Cr_5O_9	$Cr'_4O'_4$	4·014	4·000
Nitrogen sulphide	NS	$N'_4S'_6$	2·090	2·116
Sodium hydrate	$NaHO$	$Na'_4H'_4O'_4$	2·105	2·130
Zinc ,,	ZnH_2O_2	$Zn'_2H'_4O'_4$	3·046	3·053
Boric acid	H_3BO_3	$H'_3B'_2O'_3$	1·476	1·479
Sodium sulphite	$Na_2SO_310H_2O$	$Na'_4S'_6O'_4H'_4O'_2$	1·569	1·561
,, hyposulphite	$Na_2SO_35H_2O$	$Na'_4S'_6O'_4H'_4O'_2$	1·758	1·736
Potassium disulphite	$K_2S_2O_6$	$K'_4S'_6O'_4$	2·224	2·277
Sodium ,,	$Na_2S_2O_62H_2O$	$Na'_4S'_6O'_4H'_4O'_2$	2·122	2·189
Calcium ,,	$CaS_2O_64H_2O$	$Ca'_6S'_6O'_4H'_4O'_2$	2·153	2·180
Turpeth mineral	Hg_3SO_6	$Hg'_4S'_6O'_4$	8·134	8·319
Romeite	$Ca_3Sb_4O_{11}$	$Ca'_4Sb'_4O'_4$	4·737	4·714
Sodium antimonite	$NaSbO_23H_2O$	$Na'_4Sb'_4O'_4H'_4O'_2$	2·808	2·864
Silicohydric chloride	$Si_3H_4Cl_{10}$	$Si'_2H'_2Cl_3$	1·640	1·650